The Imposition and Superimposition of Digital Reading Technology: The Academic Potential of E-readers

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ABSTRACT
While rapid growth in e-reader use is receiving much attention in industry and academia, the use of e-readers for academic reading remains understudied. This qualitative study investigates how graduate students accomplish their academic reading and integrate an e-reader into their reading practices. Our work represents the first long-term study of e-reading on a production device (the Amazon Kindle DX). In this paper we contribute new knowledge to the discussion of the academic potential of e-readers by analyzing the meta-level relationship between reading tasks and associated reading techniques, students' compensation for the limitations of e-readers, and the hindrance of the human ability to construct cognitive maps of texts when using e-readers.

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Academic reading practice, design, e-book, e-reader.

ACM Classification Keywords
H.5.m. Information interfaces and presentation (I.7): Miscellaneous.

General Terms
Design, experimentation.

INTRODUCTION
E-readers are portable electronic devices often featuring E Ink technology, and are designed for reading books and electronic documents. As e-readers have become increasingly popular for leisure reading, there is a concomitant interest in exploring their potential in the academic environment, particularly for university and college students. The advantages of an e-reader over other reading technologies are encouraging: portability, legibility of text, storage capacity, long battery life, and wireless connectivity. Previous research on early e-readers shows that the presence or absence of particular features are problematic for university and college students [cf. 5,36]. While such studies report usability problems and students' failure to adopt e-readers [cf. 2,7,44], we use these findings as a starting point for our own study. We explore students' particular problem areas as part of our broader inquiry into how reading goals and preferred reading techniques are supported, or more often broken, by the introduction of an e-reader.

Our university was one of seven schools that participated in the Amazon Kindle DX pilot program, the goal of which was to evaluate the feasibility of replacing students' paper texts with electronic texts presented on an e-reader. By undertaking a qualitative research study spanning nine months supplemented with a diary study, we investigate the question, "How do students integrate e-readers into their academic reading practice?" and conclude with several implications for design. Our research confirms existing knowledge of current usability challenges; explains why e-readers still lack support for the types of reading that students do; introduces Pugh's [30] notions of reading strategies to our community; and demonstrates how these strategies play out in the adoption, use, and (in many cases) rejection of an e-reader. We contribute new knowledge regarding the academic potential of e-readers by analyzing the meta-level relationship between reading tasks and associated reading techniques, students' compensation for the limitations of e-readers, and the hindrance of the human ability to construct cognitive maps of texts when using e-readers.

E-READER USABILITY RESEARCH
E-readers are known to have usability and interaction design challenges, including difficulty with navigating digital texts, relatively poor legibility of content due to screen size and quality, and limited support for the reading practices that people use when they read paper texts.

Several researchers have developed e-reader prototypes or assessment methodologies that attempt to resolve some of these shortcomings. The XLibris [33] is designed to support information-seeking behaviors, such as looking up references, as well as collaboration by enabling users' note-taking behaviors [21]. Wilson [43] applies a specific usability assessment methodology to e-readers, concluding that e-readers should offer highly readable, navigable, and clearly formatted text in an ergonomic form factor. Chen et

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al. [4] find that their dual-screen e-reader improves navigation and re-reading compared to single-screen e-readers, but that transplanting certain affordances from paper to e-reader (such as fanning and flipping pages) is potentially more confusing than helpful to users. Schcolnik [34] provides a more thorough overview of the different features that e-readers could, or should, include to address perceived usability and interaction design issues.

In terms of the aspects of reading that change when people use e-readers, Waller describes the importance of building a cognitive map of content during active reading, a practice where "headings, illustrations and other features act as landmarks" [40]. Waller also points out that navigation is more than flipping from one page to the next. Placing one's fingers into multiple spots in a printed book is helpful as a way of quickly switching locations in a long text. Similarly, when text is not read linearly, the "cohesion cues" [40] that authors use to structure their arguments may end up being missed or ignored. These values of printed texts are imperiled when text is designed for, or read on, an e-reader.

These studies focus on understanding reading practice in the context of form factor, display technology, and feature set. However, we still lack frameworks to understand the multitude of sophisticated reading practices in which these micro-behaviors occur. For example, we already know that navigation is more than flipping from one page to the next and that people take notes and look up references. In order to inform the design of e-readers for academia, our research explores a deeper understanding of how, why, and when students switch between different kinds of reading and different types of navigation as they read academic texts.

STUDENTS' ACADEMIC READING PRACTICES

The fields of educational psychology and education offer useful frameworks for understanding academic reading, in particular the reading practices of university and college students. As described below, academic reading entails a variety of reading goals and specialized reading techniques.

Lorch, Lorch, and Klusewitz [14] situate university-level academic reading in the context of accomplishing academic goals (getting good grades, graduating, etc.). They identify four types of "school reading" situations: preparing for exams or tests; reviewing texts for research purposes; preparing for class; and reading to learn specific topics or information. These four types of school reading facilitate the achievement of broader academic goals, and are separate from six other "reading by personal choice" types unrelated to reading for academic-specific goals. School reading is "less enjoyable and much more cognitively demanding than reading by personal choice" [14]. School reading demands more attention in a variety of ways, from writing notes to connecting disparate ideas with other information to solving problems with those ideas.

The techniques that students use to read determine the amount of effort they put into school reading. Based on a study of how university students read academic texts, Pugh [30] identifies five reading techniques that students use when they read such texts; each technique requires a different level of intellectual engagement with the content. **Scanning** involves locating specific information when students know what word or phrase to look for. This technique does not involve making meaning from the text, but simply locating the desired information. **Search reading** occurs when students seek topical information without knowing exactly what text to look for.

Skimming occurs when students need to follow how the authors structured their ideas and information in their texts, and when they assess whether to engage in a different reading technique. Skimming is also useful when the structure of a text is difficult to follow and the ideas must be organized into a meaningful framework. **Receptive reading** involves reading a text from beginning to end without critically appraising the ideas, taking notes, or interrupting one's train of thought. Finally, **responsive reading** is the process of developing new knowledge or modifying existing knowledge by engaging with the ideas presented in a text. Students often engage in responsive reading, as when they annotate parts of a text. Responsive reading is essentially synonymous with active reading [cf. 1,33] or close reading [cf. 12]. We will use the phrase "responsive reading" partly because, as Adler and Doren point out, all reading is "active" [1].

These reading goals and techniques provide the necessary frameworks to understand students' e-reader use in the context of their academic reading practice. Students often mark up texts, seek out and assess references, multitask while reading, and generally do more than just read the words on the page or screen. Similarly, academic work involves a variety of navigation techniques, such as cross-referencing information within a text and across multiple texts. Studies of e-readers in academic environments indicate they are imperfect devices for these activities.

UNIVERSITY STUDENTS' E-READER USE

The small literature on college and university students' use of e-readers dates back to 1998, but has grown significantly since 2008 as e-readers have become more popular with consumers. The students in these studies had difficulty creating markup as they read, navigating from an inline reference to the list of references at the end of the text and back again, or locating illustrations quickly and viewing them with enough clarity to assess their content.

Wearden [41] provided students with an e-reader mockup and asked them to rate specific features in terms of their importance. The students considered navigation, search, and markup ability important elements of their academic reading practice. Dearnley and McKnight [5] provided students with e-readers and laptops to test their comparative usability. They found that e-reader navigation was promising but in need of improvement, even when a fiction

book was used for the study; portability and readability also ranked as important areas for improvement.

Simon [36] conducted one of the first pilot studies of e-readers on a college campus using the same e-reader as Dearnley and McKnight [5], but with an academic textbook as the text source. Simon found that students liked the storage capacity, text legibility, and portability of the e-reader; however, "glossary lookup, bookmarking, highlighting, and annotation" [36] were the most important features for the students in this study. Because features such as highlighting and annotating texts were challenging to do on the e-reader used in the study, students did not report using these features as often as predicted.

Wilson and Landoni [42] applied their methodology for studying e-readers to a usability study of five different e-readers. Search, bookmarking, and annotation were in high demand but were not regarded as easy to do with any of the e-readers. Storage capacity, portability, and features—such as the availability of a dictionary—were all noted as positive features of e-readers; although navigation was generally considered easy, study participants did not necessarily use academic texts. However, more complex navigation activities such as cross-referencing and finding one's place in a text were regarded as too difficult and led some students to say "they would not enjoy reading textbooks or papers in this manner" [42].

Fidler [7] had students assess the readability of newspaper content formatted as an e-book on a laptop, a tablet PC, and an e-reader. Two out of three students preferred the e-reader and were enthusiastic about reading text on it; however, the majority of the students expressed their desire to continue using paper rather than an e-reader to read textbooks and other academic texts. In terms of explaining which factors "influence their reading experience on mobile electronic displays," the students ranked "portability, ease of use, and readability" highest [7]. Markup ability, visually appealing content design, and battery life were also important.

Young [44] reports that e-reader navigation was so bad in one pilot program that the university switched to a computer-based e-reader technology after one semester. Additionally, students had to "adapt their [study] strategies" to use e-reader features such as annotation and highlighting. Young also finds that the use of illustrations was a major issue with both e-readers and PC-based e-books because of their illegibility and the navigation difficulties associated with finding tables and other illustrations [44].

Behler [2] reports that in a year-long e-reader pilot program, most of the students had problems with the slow refresh rate of the e-reader's pages, the navigation, and the lack of a note-taking feature. The students in this study were from a variety of fields; they pointed out that science and engineering students in particular would need to purchase paper copies of their books because the e-readers could neither render illustrations clearly nor allow users to read texts in a non-sequential manner. Students adapted their reading practice by resorting to writing notes on separate note cards and sticky notes so they could recall information without hunting through the texts again for references, specific ideas, and so on.

With regard to studies of the Kindle DX in particular, Mentch [24] found that the navigation style, including the inability to flip through multiple pages at once, the lack of color (making illustrations harder to read), and the digital rights management limitations were the major weaknesses of the device. Researchers at Princeton University found that the navigation style, including the inability to quickly flip from page to page, and the lack of PDF markup ability made the Kindle DX "occasionally…counter-productive to scholarship" [29]. Marmarelli and Ringle [16] found that the Kindle DX is not ready to replace textbooks due in part to lack of markup ability with PDF files, poor image resolution and appearance, inability to flip from page to page quickly, and inability to quickly locate a specific page or quote in the text.

As these studies make clear, certain academic reading tasks are challenging with e-readers. However, the focus on reading outcomes rather than reading processes is problematic; issues related to reading process remain underexplored in studies of e-readers in academia, partly because students' goals and techniques for reading academic texts were not considered. Our long-term, qualitative study of students' reading practices in the context of multiple reading technologies (paper, computers, and e-readers) helps fill this gap. In the remainder of this paper we describe the decisions that students make about how and why to read academic texts, and analyze how these choices define their processes of integrating e-readers into their academic reading practices.

STUDY AND METHODS

As stated earlier, our university was one of seven schools that participated in the Amazon Kindle DX pilot program. Amazon.com did not sponsor our study or assist us in collecting or analyzing data. The other schools' studies ended after one academic quarter or semester and relied primarily on surveys and focus groups to gather data; our study lasted the entire academic year and included quantitative and qualitative methods.

The Kindle DX, a larger version of the Amazon Kindle e-reader, is about 1/3 of an inch thick, weighs 18.9 ounces, and has a 9.7-inch E Ink display. The Kindle DX supports PDF documents that are 8.5 by 11 inches, which is useful for reading research articles and other documents. The controls include a physical keyboard, a five-way joystick to navigate menus and content, next page and previous page buttons, and home, menu, and back buttons. Features include an accelerometer that automatically rotates text when the device itself is rotated; text-to-speech capability;

adjustable font sizes; a dictionary; and bookmarking, annotating, and highlighting controls.

At our university, all first-year Computer Science & Engineering (CSE) graduate students received Kindle DX e-readers in lieu of printed textbooks, course packs, and required readings. Textbooks were automatically downloaded to the e-readers; the students loaded other course content themselves. All students were informed of the voluntary nature of the study at an orientation session, all students consented to participate in the pilot program, and all were allowed to keep their Kindle DXs after the program ended.

The study population consisted of 39 participants (7 women and 32 men) ranging from 21 to 53 years of age (mean: 25.6, median: 24, SD: 5.8). Of the students who described their ethnic background and nationality, 21 participants self-identified as Caucasian, 8 self-identified as Asian, 1 self-identified as Indian, and 1 self-identified as Persian. About 11% of responding participants (4 of 36) had used an e-reader before receiving their Kindle DXs for the pilot.

Data Collection

During autumn quarter (September to December 2009), we administered a demographic survey, a diary study, and semi-structured interviews using a standard protocol. During spring quarter (March to June 2010), we administered a modified version of the diary study and conducted another round of interviews with a new protocol. We modeled our diary study on similar diary studies of portable electronic devices [37]. Students wrote entries using a secure online tool available only to them. The fall quarter diary study asked students to report Kindle DX usage information, including length of time used, physical location, posture, purpose for use, features used, technologies used in conjunction with the Kindle DX, and methods used to load files onto the Kindle DX. The spring quarter diary study asked students slightly different questions about their Kindle DX usage, including information about physical location, posture, purpose for use, type of text read (textbook, research article, etc.), and technologies used in conjunction with the Kindle DX. We defined a "usage session" as "your last interaction with the Kindle when you wanted to accomplish something, no matter how small."

For the autumn quarter diary studies there were 31 unique respondents and 116 diary entries (min: 1, max: 16, SD: 3.1); during spring quarter there were 21 unique respondents and 76 diary entries (min: 1, max: 20, SD: 4.3). Therefore, 79% of the students filled out at least 1 diary entry during autumn quarter; the students filled out an entry after 73% of their reported usage sessions. During spring quarter, 54% of the students filled out at least 1 diary entry, and they filled out an entry after 71% of their reported usage sessions. While none of the 39 students dropped out of our study, 4 students never filled out a diary entry or were not available for an interview.

As a result of our analysis of these entries, we produced an interview protocol for spring quarter that consisted of 21 questions, including questions regarding the factors that help students decide when and where to read, which technologies they use when they read, and how they approach the process of reading academic texts. We interviewed students who stopped using their Kindle DXs along with those who kept using the device. All interviews were coded and analyzed by the research team using ATLAS.ti and a standard codebook developed from the interview protocol. Results reported here paraphrase or quote students from our study; all names are pseudonyms.

RESULTS AND ANALYSIS

Of the 28 students whom we interviewed during spring quarter (7 months after students received their e-readers), 64% (18 of 28) had not used their Kindle DXs for their last 3 academic readings. Although these students initially appreciated the presence of specific features such as bookmarking, annotation controls, highlighting, and Web browsing, they found these features too cumbersome to use regularly. Our spring quarter interviews probed these students' decisions to stop using the Kindle DX on a consistent basis for their academic reading; their responses are valuable in the context of developing new approaches to e-reader design. The remaining 36% of the students (10 of 28) did find ways to integrate the Kindle DX into their reading practices. Some attempted to augment e-readers with paper or computers, others became less diligent about completing their reading tasks, and still others switched to a different and usually less desirable reading technique.

In the following sections, we explore in detail the four reading tasks that our analysis revealed to have elicited the most struggles, commentary, and insight into how e-readers can break or distort existing practices: marking up texts, using references, using illustrations, and creating cognitive maps. We begin with a brief overview of descriptive statistics collected by our diary study. These statistics helped us to understand some general Kindle DX usage patterns and shed some light on how students used their e-readers in real life. We then continue to our investigation of academic reading practices and how students attempted to integrate the e-reader into their existing patterns of practice.

General Usage Overview

Our diary study findings tell the story of how and where students spent their time when they read. The students in our study typically read at home (47% of the time) or on a bus to or from school (17% of the time). They read at school 25% of the time, and at locations such as coffee shops or at an office the remaining 11% of the time. A typical usage session lasted approximately 90 to 150 minutes, although this figure varies from a few minutes to

several hours depending on the student, the available time to read, the amount of texts to be read, and so on.

Students praised the elements of the Kindle DX that improved on aspects of other reading technologies, such as the relatively lightweight form factor, long battery life, and large storage capacity. Although 61% of the students primarily sat while reading, they sometimes changed positions from sitting to reclining or lying down as they read. Finally, students used other technologies in conjunction with the Kindle DX during 49% of their usage sessions; computers and loose paper or notebooks were the most frequently used technologies. The types of academic texts read were typically textbooks in e-book or PDF format, and research articles in PDF format.

Marking Up Texts

Of the students interviewed for our study, 75% included the task of marking up texts as part of their academic reading practice. We define "markup" as any marks made on, or while reading, a text: annotations, highlights, notes and comments, underlined passages, and so on. Producing markup is a defining aspect of **responsive reading**, or using a text to develop ideas or modify existing knowledge.

In accordance with previous studies, we found a variety of ways that students mark up text, ranging from drawing on pages to writing in margins, but also marking up in parallel, where marks are made on separate papers and then interleaved with printed documents. The close juxtaposition and sometimes superimposition of the mark with the text is very important for responsive reading, and for the ability to recall thought processes and questions. For participants who habitually engaged in responsive reading, the lack of support for the easy juxtaposition or superimposition of marks was enough to precipitate abandonment of the device. For those who habitually engaged in a wider variety of reading techniques, the e-reader could still successfully support existing reading techniques.

Students reported a variety of reasons and methods for creating markup as they read. Phineas focused on highlighting key passages to understand the content more effectively or develop new ideas. Jackson drew pictures on texts so he could recall later what he was thinking as he was reading. These practices were tedious or impossible on the Kindle DX because of its lack of a touch screen or stylus drawing input, which is one reason why students found it challenging to use this e-reader for marking up texts.

In our study, all students who always marked up texts tried, and failed, to integrate the e-reader into their academic reading practice. For example, Stephanie and Phineas told us that their inability to create markup easily was the reason why they quit using the Kindle DX. Stephanie initially tried to read on her Kindle DX, keeping the same text open on her computer simultaneously and adding markup to the text on her computer. However, the slow navigation process led her to stop using the e-reader, and she switched back to her original reading practice of using Adobe Acrobat on her computer to read and mark up the text. Phineas attempted to create markup by adding annotations to the texts on his Kindle DX, but quickly switched back to using printed texts so he could add markup directly onto them as he read.

Some participants who less frequently mark up texts also considered markup to be too challenging on the Kindle DX, yet still found it useful for other tasks. For example, when Felicity needed to summarize the ideas in a text for her classmates and instructors, she read responsively. Her established practice was to print out the text and take notes in a separate notebook so she could keep all related materials together and reference them at opportune times. Felicity chose not to use her Kindle DX as part of her responsive reading practice because she preferred the "ease of random access" of ideas that paper affords. Similarly, when Steve had academic goals that required him to understand the ideas presented in a text, he engaged in responsive reading and printed out the text so he could mark it up by hand. He used paper because, as he said, "I don't want to miss details, I want to take down notes, and I want to absorb [the text], not just read it." He believed that paper supported responsive reading most effectively precisely because he marked up texts as he read, which he considered too difficult to do on the Kindle DX.

When they did not have specific academic goals that required a deep understanding of a text, or when they found it too physically challenging to create markup (such as while commuting on a crowded bus), Felicity and Steve read texts from beginning to end without jumping to other sections. This technique of **receptive reading** closely matches the sequential process of leisure reading, such as reading a fiction novel from one chapter to the next without jumping a few chapters ahead. Thus, although the Kindle DX was poor for *responsive* reading, which typically involves marking up, they found that it was still acceptable for *receptive* reading situations.

Using References in Academic Texts

References are the connective tissue of academic writing: The references in one article lead to related articles that contain additional useful information. Of the students interviewed for our study, 21% typically used references to assess the quality or relevance of a text, or to discover new and potentially relevant texts. The students who use references in this way rely on the **skimming** reading technique to quickly review texts and locate potentially useful information, such as a reference of interest.

However, the Kindle DX is not designed to enable the rapid, non-sequential use of text that skimming requires. For example, when Alan skims a text, he quickly glances through an entire article to get an overview of the content and main points. While skimming, Alan sometimes notices an interesting reference. When this happens, he stops skimming and starts responsively reading: He navigates to

the list of references at the end of the article, traces the reference of interest to its entry in a research database, and then reviews the abstract to see whether it could be germane to his own work. All of this work is considered responsive reading because Alan is using the information to stimulate his own thought process about the content [30].

The Kindle DX is not designed to support this sort of workflow; although there is a Web browser included on the device, the students told us that it was too slow and too difficult to navigate content to be useful. Therefore, students who chose to use the Kindle DX to meet their academic goals also had to choose between changing their existing reading practice to accommodate the Kindle DX, or being less thorough about performing undersupported reading tasks such as using references.

David chose to adapt his reading practice to include the Kindle DX as his primary technology for reading academic texts. However, he discovered that he looked up references less frequently because he could not quickly navigate through the content. He solved this problem by reading his Kindle DX while sitting near his computer so he could look up references at the computer as he read. Although this process was less efficient than simply reading texts on his computer, David liked using his Kindle DX because of its portability, storage capacity, and long battery life. As a result of these benefits, he was willing to modify his reading practice and include his preferred reading technology while still supporting his reading task.

Martin initially chose to adapt his reading practice and use the Kindle DX to read texts assigned to him in his reading groups. His new practice was to read those assigned texts using his Kindle DX and write down the numbers of interesting references on a separate sheet of paper, a practice that echoes the results of Behler [2]. Martin would then cross-reference the numbers he wrote down with the references listed in the article, and look up those references using his computer. However, he looked up references less often because of the extra effort required to locate them; as he put it, "I ended up…changing my behavior there and just blowing that off for the papers that I was reading on the Kindle." In this way, Martin was less thorough about performing the reading task of using references.

Rather than change their reading practice or perform their reading tasks less thoroughly, other students inserted the Kindle DX into specific areas of their practice for which an e-reader is better suited than paper or computers. Newman recognized that navigation on the Kindle DX was too slow to look up references quickly. Therefore, he retained his previous practice of skimming or responsively reading text on paper so he could use the references in the text. He limited his Kindle DX use to certain situations (such as commuting to school on the bus or reading while walking) when he did not use the skimming or responsive reading techniques. At those times, Newman's existing reading practice was to read receptively and not attempt to complete any specific reading tasks. He made this choice because he felt the Kindle DX supported his reading technique and his mobility more effectively than other reading technologies.

When faced with the task of using references on the Kindle DX, some students modify their reading practice around the new technology, while others retain the same practice but perform specific tasks less effectively than before. Still others find a niche for the new technology without changing their practice or their task effectiveness. These different resolutions reflect the myriad ways that students decide how to integrate an e-reader such as the Kindle DX into their academic reading practice.

Using Illustrations in Academic Texts

Students' comprehension of reading material is jeopardized when illustrations are not presented legibly or in their proper context. Of the students interviewed for our study, 25% always reviewed illustrations to evaluate the relevance of the content or understand the content in more detail. By "illustrations," we refer to tables, figures, equations, and other visuals often found in scientific and engineering texts.

Due to e-reader screen quality and formatting constraints, the details within illustrations sometimes appear grainy or fuzzy and often cannot be placed with their corresponding text. However, illustrations need to be viewed within their proper context for readers to accurately evaluate them and the texts in which they are included [3,8,23]. This issue is important because students read academic texts to meet specific goals, such as studying for an exam or writing a research paper. They have limited time in which to complete their reading tasks, so they **skim** texts to extract the essential ideas and decide which parts to read in greater detail. Skimming enables students to assess the presentation and validity of the ideas before they commit to using a reading technique that requires more mental effort and takes more time, such as **responsive reading**. Therefore, they skim until they encounter an illustration that requires interpretation, and then they switch to responsive reading and critically analyze the information being presented.

The Kindle DX makes this technique-switching process challenging. For example, Janice would skim a text and look at the illustrations first before deciding whether to read the text responsively. She had difficulty supporting this process with the Kindle DX because of the excessive page-by-page navigation required to jump several pages ahead and back again. However, she found a way to integrate the Kindle DX into her reading practice: She began writing key information about an illustration on a separate piece of paper so she could recall specific details about it as she flipped through the rest of the text. In this way, she was able to continue switching between skimming and responsive reading to complete her academic reading.

Accessing the illustration is only part of the process of comprehension, however: Even when students found the illustrations, they were frequently unable to discern what

the illustrations depicted because of the low fidelity of the E Ink display. Jackson found the quality of illustrations on the Kindle DX problematic because, while viewing a PDF document, he noticed typos in an illustration. When he reviewed the same illustration in the same PDF on his laptop, the typos were not present. The cause of the typos was the E Ink display technology: The fine detail of the illustration was rendered inaccurately on the Kindle DX. Jackson needed to use the information conveyed in the illustration to complete a homework assignment; had he used the information as presented on the Kindle DX, his work would have been incorrect. This experience convinced Jackson to stop using the Kindle DX for academic reading.

David preferred reading texts on his Kindle DX, and when he encountered this issue, he chose to skim the text on his Kindle DX until he encountered a reference to an illustration, at which point he switched to the same text on his computer to locate and interpret the meaning of the illustration. David told us his responsive reading was less effective as a result of this new practice because his attention to the meaning of the text was disrupted. Instead, his attention was directed to shifting from one reading technology to another, finding his place in both versions of the text, and then going about his reading task. David kept losing his train of thought as he read, a phenomenon that he told us negatively impacted his content comprehension.

The Kindle DX required students to pay so much attention to the process of accessing content, they felt that they extracted less value from the texts they read on this device. For those students who persevered with usage of the Kindle DX, they felt it was necessary to supplement it with another reading technology to assist their comprehension of illustrations. However, this choice resulted in less attention paid to the content of a text, and more attention paid to the process of using texts. This change in reading practice has potentially negative consequences for students' levels of productivity, learning outcomes, and ability to meet their academic goals.

Using Cognitive Maps as Learning Aids

When we read, we unconsciously note the physical location of information within a text and its spatial relationship to our location in the text as a whole. This phenomenon is variously described as creating spatial layouts and acquiring incidental knowledge of the location of information within a text [26], spatial memories [35], and cognitive representations [39]; we refer to the human ability to unconsciously link ideas and their physical locations within the texts we read as cognitive mapping [40]. In our study, 25% of the students we interviewed brought up the topic of cognitive mapping, telling us they created such maps when they read.

The term "cognitive map" is traditionally used in the fields of learning science, psychology, and HCI in the context of physical and virtual environments. For example, Elvins defines cognitive maps as "an internal representation of an environment gained by a comprehensive set of observations…used to travel between locations in the environment" [6]. Similarly, Johns defines cognitive maps as "a mental image of a place" [11]. These mental images and representations do more than just help us recall where ideas are located in a given text. We use cognitive maps to retain and recall textual information more effectively [15,27,31], making them useful tools for students who are reading academic texts to satisfy specific goals.

Previous research cites the dynamic location of content and the increased scrolling required due to the small screen size [10,27] as the primary reasons why it is difficult to construct cognitive maps when using an e-reader. The students in our study not only cited the dynamic content location as an issue with the Kindle DX, but also told us their physical experience with the text changed dramatically because they missed the physical, or kinesthetic, interactions of other reading technologies. People use their spatial and kinesthetic knowledge to assist them with a variety of interfaces [13]; it is also clear that "kinesthetic cues "aid spatial memory" [38].

E-readers strip away some of these kinesthetic cues because there is no tangible page to turn and no scroll bar to drag. Texts presented on paper or on computer screens provide an interactive sense of how much text remains to be read, how much has already been read, and how to quickly relocate a portion of content that has already been read. The students in our study who told us they create cognitive maps of content confirmed that this task was challenging when using an e-reader for academic work.

For example, Robin used kinesthetic cues such as folded page corners and the tangible weight of the printed book to help him locate content quickly. He told us that "after I've spent some time with the physical book, I know…exactly how to open it to the right page…. I kind of visually can see where I am in the book." His physical experience with the text changed dramatically when he began using his Kindle DX: He lost these kinesthetic cues and spent much more time hunting for information than he had previously done. He stopped using the Kindle DX for his assigned academic readings because he wanted to remain as productive and efficient as he was before he received his Kindle DX.

Naomi used academic texts in the same way as Robin and also placed a great deal of value on her construction of cognitive maps as part of her academic reading practice. She used her cognitive maps to remember later where certain ideas were located in the text. These memories were important to her because, when she needed to write a research paper on a specific topic, she used kinesthetic cues to locate relevant content where she remembered seeing it previously. Naomi discovered that the Kindle DX did not support the development of these cues or of cognitive maps, which resulted in more work for her when she needed to locate specific content upon rereading a text.

Naomi and the other students who discussed cognitive mapping independently reached the same conclusion: The Kindle DX does not effectively support building cognitive maps. The lack of support is due to the fragmentation of ideas and concomitant difficulty with skimming, the lack of kinesthetic cues, and the loss of spatial knowledge about the location of specific content. Students are accustomed to creating cognitive maps automatically as part of their standard academic reading practice. When they have no cognitive maps on which to rely, the process of locating information takes longer, they have less mental energy for other tasks, and their ability to maintain their desired levels of productivity suffers. This is an important finding that bears further study and that presents a crucial design problem for future e-readers to resolve.

DISCUSSION AND IMPLICATIONS FOR DESIGN

Our interviews of graduate students about particular reading tasks led us to develop an understanding of how academic reading is embedded within a larger set of practices. By focusing on particular problem areas, we were able to elicit information about their academic goals. These goals necessitate specific reading techniques, which in turn call for different reading tasks, such as taking notes or looking up a reference to another research paper. Students move fluidly from technique to technique as they complete tasks; the aggregation of these processes describes students' academic reading practices, which are constructed over a lifetime of academic work. Reading technologies such as e-readers, paper, and computers are used selectively or together in the service of supporting these practices.

Before the process of inserting an e-reader into an academic environment can succeed, it is necessary to grapple with what actually occurs during academic reading [28]. Considerable amounts of previous research have indicated the importance of supporting responsive reading tasks for work in general. Golovchinsky argues that e-reader technology is useful because of its computing power and ability to augment the "active reading" [9] of office work, the elements of which (such as annotating or quoting content) mirror academic work. Similar studies of these elements of responsive reading tasks include practices of annotation [17,19,26], use of multiple documents simultaneously [26], dynamic arrangement of information in space [26], use of different reading techniques [12,18,32], multitasking while reading [22], and use of different information navigation techniques [20,22].

The goal of all of these tasks is the same: to generate new knowledge by using information gathered from existing texts. For example, when they complete homework assignments or author research papers, students reuse and restate existing knowledge in these new texts. This process of applied learning is foundational to academic reading and is best achieved by making sense of texts using the tasks associated with responsive reading. However, as we have made clear in this paper, e-readers are not designed to support responsive reading tasks such as marking up, switching between reading techniques, and so on.

Therefore, our research *confirmed the importance of supporting responsive reading techniques, as well as the need to support students' generation of new texts based in part on the knowledge they gain when reading responsively*. E-readers cannot be successfully adopted in academia without such support. Academic reading is not a single, monolithic practice that e-readers do or do not support [25]; the success of an e-reader in academia resides in its designed ability to support the aggregate of students' reading techniques in general and the tasks associated with responsive reading in particular.

A new finding from our study is that students routinely switch between reading techniques: from skimming to responsive reading and back again, from scanning to responsive reading, etc. These other techniques help students decide which material they will read responsively, and are interspersed with responsive reading. Thus, *in order to effectively support responsive reading, it is necessary to support seamless switching between different reading techniques*.

Participants varied considerably by how much time they spent using and switching between various reading techniques, the types of markup they created (drawing, annotations), and how they preferred to access and use references. Further, participants' idiosyncratic reading styles are purposeful; their switches among reading techniques precipitate particular kinds of navigational requirements. Effective navigation for academic reading requires supporting navigation anywhere in the document, multiple simultaneous bookmarking, flipping between reference lists, a hyperlinked table of contents, legible and easily locatable illustrations, and a simple path back to an easily resettable start page. Navigational needs for academic reading are diverse: *to effectively support navigation it is important to consider who is navigating (e.g., a CS graduate student), the intended goal (e.g., an exam; research; homework), the types and proportion of reading techniques (e.g., skimming, receptive reading, responsive reading), and the types of textual items (illustrations, reference lists)*.

Another new finding from our study connects students' academic goals with their decisions to use their e-readers opportunistically. The Kindle DX supported receptive reading very well, but did not support responsive reading and scanning well at all. By studying the adoption of the Kindle DX over time, we developed an understanding of the strategies students used while adopting (or deciding not to adopt) the e-reader. We learned that, *for students who usually undertake responsive reading, the lack of support for juxtaposed or superimposed markup is reason enough to abandon the device. For students who less frequently mark up texts, they use their e-readers opportunistically when engaging in reading techniques that are well supported*.

At the same time, students who engaged in poorly supported reading techniques often used e-readers in concert with other reading technologies to produce a facsimile of how they had worked before using an e-reader. For example, instead of writing on a paper text or typing a note in a PDF file, a student may place a piece of paper next to the e-reader on which to note interesting references. The *necessity of augmenting the e-reader with a separate reading technology is not problematic per se, but is problematic in terms of how it "breaks" existing practice.*

Students use multiple reading technologies simultaneously: They need to be near their computers, paper texts, and other tools of their academic work to complete their academic readings [2,4,21,22]. Marshall and Ruotolo [22] describe this situation by saying that "reading [is] a hybrid activity," meaning that the act of reading for academic purposes involves "a larger system of documents, technologies, and reading-related activities" rather than a single text in isolation. However, the need to supplement e-reader technology is problematic because, for certain reading practices, it does not afford the benefits of having marks on the original document. Students create these marks while reading responsively and use them later for scanning, skimming, and cognitive mapping for recall. Although the Kindle DX supports a rudimentary annotation system, *the ability to superimpose or juxtapose marks on texts is crucial for responsive reading, but also for other types of reading that may have different goals* (e.g., writing an analytical paper versus reviewing for a meeting or exam). It remains unclear whether design solutions such as multiple screens would solve this issue for student users of e-readers.

CONCLUSION

A successful future for e-readers in academia depends on understanding how to support students' varied reading practices more effectively. The students in our study struggled, and sometimes succeeded, at integrating the e-reader into their academic reading practices. Rather than focusing on the low rate of adoption as an endpoint, we explored the larger context around e-reader "pain points" of creating markup, using references and illustrations, and building cognitive maps. Our data revealed that students routinely switched back and forth between reading techniques, and that different techniques engendered different ways of using text. Future research on the relationships among the constellation of techniques, tasks, page elements (e.g., references), and academic goals—and how these dovetail with larger academic workflows involving production of texts—will yield a richer understanding of design requirements for e-readers, and of the very design space itself.

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